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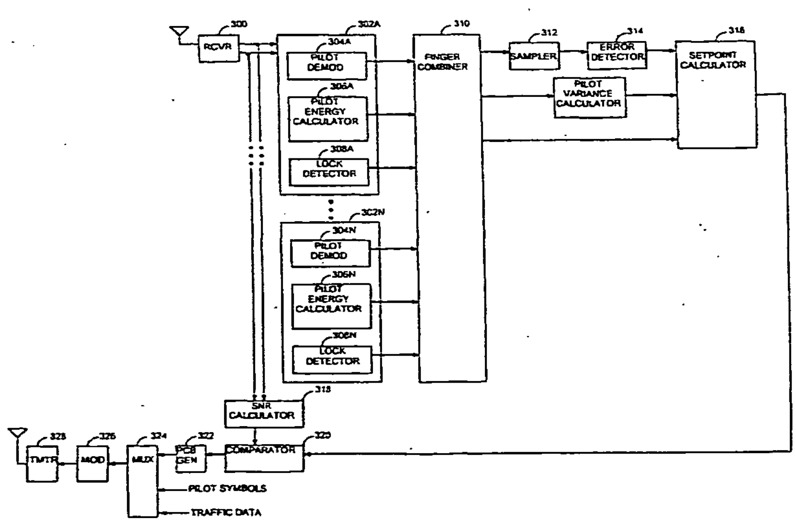

(57) Abstract: The present invention is a novel and improved method and apparatus for performing closed loop power control. A method of implementing reverse link outer loop using only pilot signal is described. Such a method is especially useful when the data signals are only present in short burst such that packet or frame error rates (PER or FER) cannot be estimated accurately. Moreover, since this method provides a mechanism for accurate set point adjustment even without a PER (FER) estimate, it can also be used to improve the accuracy of outer loop performance when such estimate becomes available. The present invention estimates a "pilot bit error rate" (PBER) (200), where each pilot "bit" consists of a number pilot chips distributed over a frame. In addition, it estimates the normalized variance of the signal energy (or C/I) (202) for each packet.

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METHOD AND APPARATUS FOR DETERMINING THE CLOSED LOOP POWER CONTROL SET POINT IN A WIRELESS PACKET DATA COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communications. More particularly, the present invention relates to a novel and improved method and apparatus for controlling transmission energy in a wireless communication system.

II. Description of the Related Art

The use of code division multiple access (CDMA) modulation techniques is one of several techniques for facilitating communications in which a large number of system users are present. Other multiple access communication system techniques, such as time division multiple access (TDMA) and frequency division multiple access (FDMA) are known in the art. However, the spread spectrum modulation technique of CDMA has significant advantages over these modulation techniques for multiple access communication systems. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein. The use of CDMA techniques in a multiple access communication system is further disclosed in U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein.

CDMA by its inherent nature of being a wideband signal offers a form of frequency diversity by spreading the signal energy over a wide bandwidth. Therefore, frequency selective fading affects only a small part of the CDMA signal bandwidth. Space or path diversity is obtained by providing multiple signal paths through simultaneous links from a mobile user through two or more cell-sites. Furthermore, path diversity may be obtained by exploiting the multipath environment through spread spectrum processing by allowing a

signal arriving with different propagation delays to be received and processed separately. Examples of path diversity are illustrated in U.S. Patent No. 5,101,501 entitled "METHOD AND SYSTEM FOR PROVIDING A SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM", and U.S. Patent No. 5,109,390 entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention and incorporated by reference herein.

A method for transmission of speech in digital communication systems that offers particular advantages in increasing capacity while maintaining high quality of perceived speech is by the use of variable rate speech encoding. The method and apparatus of a particularly useful variable rate speech encoder is described in detail in U.S. Patent No. 5,414,796, entitled "VARIABLE RATE VOCODER", assigned to the assignee of the present invention and incorporated by reference herein.

The use of a variable rate speech encoder provides for data frames of maximum speech data capacity when said speech encoding is providing speech data at a maximum rate. When a variable rate speech coder is providing speech data at a less that maximum rate, there is excess capacity in the transmission frames. A method for transmitting additional data in transmission frames of a fixed predetermined size, wherein the source of the data for the data frames is providing the data at a variable rate is described in detail in U.S. Patent No. 5,504,773, entitled "METHOD AND APPARATUS FOR THE FORMATTING OF DATA FOR TRANSMISSION", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein. In the above mentioned patent application a method and apparatus is disclosed for combining data of differing types from different sources in a data frame for transmission.

In frames containing less data than a predetermined capacity, power consumption may be lessened by transmission gating a transmission amplifier such that only parts of the frame containing data are transmitted. Furthermore, message collisions in a communication system may be reduced if the data is placed into frames in accordance with a predetermined pseudorandom process. A method and apparatus for gating the transmission and for positioning the data in the frames is disclosed in U.S. Patent No. 5,659,569, entitled "DATA BURST RANDOMIZER", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein.

A useful method of power control of a mobile in a communication system is to monitor the power of the received signal from the mobile station at a base station. The base station in response to the monitored power level transmits power control bits to the mobile station at regular intervals. A method and apparatus for controlling transmission power in this fashion is disclosed in U.S. Patent No. 5,056,109, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein.

In a communication system that provides data using a QPSK modulation format, information regarding the transmitted data signal can be obtained by taking the cross product of the I and Q components of the QPSK signal with the estimate of the communications channel. By knowing the relative phases of the two components, one can determine roughly the velocity of the mobile station in relation to the base station. A description of a circuit for determining the cross product of the I and Q components with the channel estimate in a QPSK modulation communication system is disclosed in U.S. Patent No. 5,506,865, entitled "PILOT CARRIER DOT PRODUCT CIRCUIT", assigned to the assignee of the present invention, the disclosure of which is incorporated by reference herein.

There has been an increasing demand for wireless communications systems to be able to transmit digital information at high rates. One method for sending high rate digital data from a remote station to a central base station is to allow the remote station to send the data using spread spectrum techniques of CDMA. One method that is proposed is to allow the remote station to transmit its information using a small set of orthogonal channels, this method is described in detail in copending U.S. Patent No. 08/886,604, entitled "HIGH DATA RATE CDMA WIRELESS COMMUNICATION SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein.

FIG. 1 illustrates a conventional system for generating closed loop power control commands. A signal is received at an antenna and provided to receiver (RCVR) **100**. Receiver **100** down converts, amplifies and filters the received signal and provides the received signal to demodulator **102**. Demodulator **102** demodulates the received signal. Within demodulator **102**, is a channel estimate generator (not shown), which estimates the channel characteristics based on a transmitted signal with values known to both the transmitter and the receiver, referred to herein as the pilot signal. The pilot signal is

demodulated and the phase ambiguities in the received signal are resolved by taking the dot product of the received signal and the pilot signal channel estimate. The demodulated signal is typically provided to a deinterleaver, which reorders the demodulated symbols in accordance with a predetermined reordering format.

The reordered symbols are provided to decoded **106**. The decoded symbols are then optionally provided to a cyclic redundancy check (CRC) bit check element **107**. CRC check element **107** locally generates a set of CRC bits from the decoded data and compares those locally generated bits with the estimated received CRC bits. CRC check element **107** provides a signal indicative of the checking of the CRC bits to control processor **110**. In addition, decoder **106** may provide other quality metrics such as Yamamoto metric or symbol error rate to control processor **110**. In response, control processor **110** outputs either the decoded frame of data or a signal indicative of the erasure of a frame.

In any communication system there is a nominal performance rate. In conventional systems, the performance is determined based upon the frame error rate of the received signal. The frame error rate depends on the average received signal to noise ratio of the received signal or other quality metric related to the received signal. When the frame error rate is less than the target frame error rate, the power control set point is decreased. Conversely, when the frame error rate is greater than the target frame error rate, the set point is increased. In one method for adjusting the signal to noise ratio threshold, the set point is increased by a relatively large amount, for example 1dB, whenever a frame erasure is detected. Conversely, the signal to nose ratio threshold is decreased by 0.01 dB whenever a frame is properly decoded. Control processor **110** provides the set point to comparator (COMP) **112**. In a pilot assisted coherent communication system, the signal to noise ratio is estimated based on the pilot signal. An exemplary method for estimating the signal to noise ratio based on the pilot signal is disclosed in copending U.S. Patent Application Serial No. 08/722,763, filed September 27, 1996, entitled "METHOD AND APPARATUS FOR MEASURING LINK QUALITY IN A SPREAD SPECTRUM COMMUNICATION SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein.

The demodulated signal from demodulator 102 is provided to signal to noise ratio calculator (SNR CALC) **108**. Signal to noise ratio calculator **108** computes the signal energy based on the energy of the demodulated symbols.

In addition, a signal indicative of the received in band energy is provided to signal to noise ratio calculator **108**. Signal to noise ratio calculator **108** generates an estimate of the signal to noise ratio of the received signal and provides this estimate to comparator **112**.

In comparator **112**, the estimated signal to noise ratio is compared with the power control loop set point provided by control processor **110**. A signal indicative of the result of the comparison is provided to power control bit generator **114**. If the estimated SNR is less than the set point, then power control bit generator **114** provides a message requesting that the transmitting device increase the energy of its transmissions. If the estimated SNR is greater than the set point, then power control bit generator **114** provides a message requesting that the transmitting device decrease the energy of its transmissions.

The power control message which is a single bit message requesting the transmitting device to increase or decrease its transmission energy by a predetermined amount is provided to puncturing element **118**. Puncturing element **118** receives modulated traffic data from traffic modulator **120** and punctures the power control message into the traffic data in a predetermined fashion. The traffic data including the power control data is then upconverted, filtered and amplified for transmission to the transmitting device. In response the power control messages, the transmitting device (not shown) increases or decreases the energy of its transmissions in a predetermined fashion.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus for performing closed loop power control. A method of implementing reverse link outer loop using only pilot signal is described. Such a method is especially useful when the data signals are only present in short burst such that packet or frame error rates (PER or FER) cannot be estimated accurately. Moreover, since this method provides a mechanism for accurate set point adjustment even without a PER (FER) estimate, it can also be used to improve the accuracy of outer loop performance when such estimate becomes available. The present invention estimates a "pilot bit error rate" (PBER), where each pilot "bit" consists of a number pilot chips distributed over a frame. In addition, it estimates the normalized variance of the signal energy (or C/I) for each packet. In addition, in the preferred embodiment, the average number of fingers that are in lock is also used to determine the power control set point.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a block diagram of a closed loop power control system;

FIG. 2 is a flowchart illustrating the preferred method for determining the closed loop set point of the present invention;

FIG. 3 is a block diagram illustrating the apparatus for generating closed loop power control commands of the present invention;

FIG. 4 is a block diagram illustrating the method of generating metrics to be used in the in the determination of the closed loop set point; and

FIG. 5 is a block diagram illustrating an exemplary apparatus for determining the normalized signal variance for determination of the closed loop set point.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention describes a method of determining the set point of a closed loop power control system. In the exemplary embodiment, the present invention is applied to a packet data transmission system. In packet data transmission systems, data is transmitted in bursts and a significant period of time may elapse between the burst transmissions. In the exemplary embodiment, a pilot signal is transmitted even when no packet data is being transmitted. The exemplary embodiment of the present invention is discussed in terms of a system optimized for packet data transmission in a wireless communication system as described in detail in copending U.S. Patent Application Serial No. 08/963,386, filed November 3, 1997 and entitled "METHOD AND APPARATUS FOR HIGHER RATE PACKET DATA TRANSMISSIONMETHOD AND APPARATUS FOR HIGHER RATE PACKET DATA TRANSMISSION", which is assigned to the assignee of the present invention and incorporated by reference herein. The present invention may also be extended to other proposed systems that are planned to carry packet data transmissions, such as the Telecommunications Industry Association proposal to the International Telecommunications Union (ITU) entitled "The cdma2000 ITU-R RTT Candidate Submission" and the European Telecommunications Standard Institute proposal to the

International Telecommunications Union (ITU) entitled "The ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT Candidate Submission".

The present invention is especially useful when the data signals are transmitted in short bursts so that packet or frame error rates (PER or FER) cannot be estimated accurately. Such cases are quite common in a wireless packet data system such as described in the aforementioned U.S. Patent Application Serial No. 08/963,386. Moreover, since the present invention provides a mechanism for accurate set point adjustment even without PER (FER) estimate, it can also be used to improve the accuracy of outer loop performance when such estimate becomes available.

The present invention describes setting the power control set point based on a "pilot bit error rate" (PBER), where each pilot "bit" consists of a number pilot chips distributed over a frame. In a preferred embodiment of the present invention, the set point is determined additionally in accordance with a normalized variance of the signal energy (or signal to noise interference) per slot for each packet and additionally employs the number of fingers in lock to determine the set point. By employing these two additional factors the set point can be determined to provide a good indication of PER (FER) almost independent of the channel characteristics, e.g. different Doppler spectrum. Thus, it is possible to determine the closed loop power control set point (T) based on these factors.

In the exemplary embodiment, there are 2048 chips in each slot organized as 32 groups with 64 chips each. The first 64 chips (zero'th group) is the reverse rate indicator (RRI). The rest of the even groups consists of the pilot signal and the odd groups are multiplexed control bits. Only the pilot signal groups are used in the set point determination method of the present invention. Two quantities generated from the pilot signal that are used by the outer loop are pilot bit error rate (PBER) and the normalized variance of the pilot energy.

Referring to FIG. 2, a method of determining the power control set point on the received pilot signal is illustrated. In block **200**, the pilot bit error rate (PBER) is computed. In the exemplary embodiment, the pilot channel is modulated by spreading each symbol of the all zeroes symbol sequence using a four chip Walsh(0) sequence and pseudonoise (PN) sequence. One skilled in the art will readily appreciate that the present invention is equally applicable to other pilot channel structures. The first step in computing the pilot bit error rate is to despread the received samples. In the exemplary embodiment, the received samples are despread in accordance with a 4 chip Walsh(0) sequence and the PN sequence to provide 240 despread pilot samples in each slot.

The despread pilot samples are delayed and demodulated by the channel estimate. In the exemplary embodiment, the pilot signal is transmitted on the in-phase

component of a QPSK modulated signal. In the exemplary embodiment, the real parts of the corresponding demodulated pilot samples of all the slots in a frame are combined to form 240 estimates of the pilot symbols. In the exemplary embodiment, the pilot symbols are the all zeroes sequence represented by a positive amplitude value. Conversely, one value symbols are represented with negative amplitudes. At the end of each frame, these samples are compared to zero. If any estimate is less than zero a pilot bit error is declared. By adjusting the power control set point to make the frame error rate equal to 1%, the number of average bit error per a frame is given in Table 1 for the case of two antennas with one path per antenna. Thus, in the simplest case the pilot bit error rate can be used to derive the set point by having knowledge of the motion of the transmitter relative to the receiver.

In step **202**, the normalized signal variance is calculated. While the PBER is related to the frame error rate, it also a function of vehicle speeds and other channel characteristics. An improved embodiment of the present invention describes a method for compensating for the effect of vehicle speed by using the normalized variance of the received signal power or C/I as described below.

In the exemplary embodiment, the closed loop power control commands are transmitted 600 times per second, i.e., a power command is generated every slot. In the exemplary embodiment, the normalized signal power variance (ρ) is defined as:

$$\rho = \sqrt{\frac{\overline{p(n)^2} - \overline{p(n)}^2}{\overline{p(n)}^2}} = \sqrt{\frac{\overline{p(n)^2}}{\overline{p(n)}^2} - 1}, \tag{1}$$

where p(n) is the measured power of the nth frame, $\overline{p(n)^2}$ is the average of the squared energy of the demodulated pilot symbols for the current frame, and $\overline{p(n)}^2$ is the average energy of the demodulated pilot symbols squared for the current frame.

Referring to Table 1 below, it can be observed that the pilot bit error rate and the normalized signal variance have different trends with respect to vehicle speed. Thus, it is possible to construct a linear combination of these two quantities, PBER+$\alpha_1\rho$, which is nearly a constant independent of vehicle speeds as shown in Table 1.

Vehicle Speed	0 kmph (AWGN)	3 kmph	10 kmph	30 kmph	120 kmph
Pilot bit error per frame	5.29	4.5	4.036	3.33	3.58
ρ	0.5	0.55	0.76	0.88	0.825
PBER+$\alpha_1\rho$ (α_1=4.0)	7.29	6.7	7.54	6.85	6.88

Table 1

Practically, the average estimates of p and p^2 can be computed by passing these estimates through a single pole low-pass filter defined as:

$$\overline{p}(n) = c_1 \cdot \overline{p}(n-1) + c_2 \cdot p(n) \tag{2}$$

and

$$\overline{p^2}(n) = c_3 \cdot \overline{p^2}(n-1) + c_4 \cdot p^2(n) \tag{3}$$

where n is the frame index. In the exemplary embodiment, c_1 and c_3 are equal to 0.95 and c_2 and c_4 are equal to 0.05.

In block **204**, the number of fingers in lock is computed. In the process of RAKE reception, the signal strength of each demodulated finger is computed. The signal strength must be in excess of a threshold value in order for it to be soft combined by the RAKE receiver. When the signal strength is sufficient that it is worthy of being soft combined, the finger is said to be "in lock". In the improved embodiment, the impact of multiple fingers is compensated for by making the set point a function of the average number of fingers that are in lock (N_f). In the exemplary embodiment, a determination as to whether a finger is in lock is conducted for each slot. In the exemplary embodiment, the average number of fingers in lock is computed by summing the number of fingers in lock for each slot in the frame and dividing by the number of slots in a frame.

In block **206**, the set point is calculated. The first step in calculating the set point is to generate a metric (η) that is a function of the three factors described above. In the improved embodiment, the following metric described above is modified by the addition of a term that is a linear function of N_f, the number of fingers, works quite well.

$$\eta(n) = \mathrm{PBER}(n-1)+\alpha_1\rho(n-1)+\alpha_2 N_f(n-1), \tag{4}$$

where, in the exemplary embodiment, where $\eta(n)$ is the metric for the current (nth) frame, PBER(n-1) is the pilot bit error rate for the previous ((n-1)st) frame and $\rho(n-1)$ is the pilot variance for the previous ((n-1)st) frame, $N_f(n-1)$ is the number of fingers in lock in the previous frame and α_1 and α_2 are scaling constants equal to 4 and 0.9, respectively.

From Table 1, the outer-loop threshold is set to be 6.75 for α_1 of 4.0. The outer loop threshold can be improved by accumulating statistics regarding the frame error rate. An error for the current frame ($\varepsilon(n)$) is calculated according to the equation:

$$\varepsilon(n) = \eta(n) - 6.75. \tag{5}$$

The set point for the current frame (T(n)) is modified according to the equation:

$$T(n) = T(n-1) + \Delta\varepsilon(n) \tag{6}$$

where in the exemplary embodiment, Δ is approximately 0.02.

FIG. 3 illustrates the exemplary embodiment of the apparatus for determining the set point of the present invention. The signal is received at an antenna and provided to receiver **300**. Receiver **300** downconverts, amplifies and filters the received signal. In the exemplary embodiment, receiver **300** down converts the received signal in accordance with a quaternary phase shift keying (QPSK) format and provides the resultant in-phase and quadrature-phase components to metric calculators **302**. In the exemplary embodiment, a separate metric calculator **302** is provided for each finger being demodulated by the receiver system.

In each of metric calculators **302**, pilot demodulator (PILOT DEMOD) **304** demodulates the received pilot symbol stream to provide estimates of the received pilot symbols and provides those demodulated pilot symbols to finger combiner **310**. In each of metric calculators **302**, pilot energy calculators **306** compute the energy of received pilot symbols and provide the measured energies to finger combiner **310**. In addition, in each of metric calculators **302**, lock detectors **304** determine whether the finger corresponding to the metric calculator **302** is in lock. Diversity reception in a CDMA communication system is well known in the art and is described in detail in aforementioned U.S. Patent No. 5,109,390.

Finger combiner **310** sums the demodulated pilot symbol energies from each of pilot demodulators **304** , sums the pilot symbol energies from each of

pilot energy calculators **306** and sums the number of fingers determined to be in lock to provide the number of fingers in lock value N_f.

The combined pilot symbols are provided to optional sampler **312**. Sampler **312** decimates the demodulated pilot symbols stream and provides the decimated stream to error detector **314**. Because the values of the transmitted symbols are known to the receiver, detecting errors comprises comparing the received pilot symbol estimates decimated or intact to the expected pilot symbol sequence. In the exemplary embodiment, the pilot symbols are the all zeroes sequence, which are in represented as a positive amplitudes. Thus whenever the demodulated pilot symbol has a negative amplitude, a pilot bit error is declared by error detector **314**. The number of detected pilot bit errors (PBER) is provided to set point calculator **316**.

The combined pilot symbol energies, p(n), are provided to pilot variance calculator **315** which computes the normalized signal variance $\rho(n)$ as described in equations (1)-(3) above and provides the result to set point calculator **316**.

Each of metric calculators **302** provides a signal indicative as to whether the finger to which the metric calculator is assigned is in lock during that slot. Finger combiner **310** sums the number of slots for which each of the fingers is in lock and divides by the number of slots in a frame to provide the average number of fingers in lock N_f. Finger combiner **310** provides a signal indicative the value N_F to set point calculator **316**.

In the preferred embodiment, set point calculator **316** determines the set point (T) in accordance with equations (4)-(6) above. Set point calculator **316** provides the set point (T) to comparator **320**. Receiver **300** provides the base band samples to signal to noise ratio calculator **318**. A large number of methods are known in the art to estimate the signal to noise ratio. A simple method for estimating the noise energy is to assume all in band energy is noise. Receiver **300** typically includes an automatic gain control (not shown) device and the in-band energy can typically be estimated based on the scaling of the received signal by the automatic gain control device. The signal energy can be estimated based on the energy of the demodulated traffic symbols. A number of methods for estimating the signal to noise ratio are disclosed in copending U.S. Application Serial No. 08/722,763, filed September 27, 1996 and entitled "METHOD AND APPARATUS FOR MEASURING LINK QUALITY IN A SPREAD SPECTRUM COMMUNICATION SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein.

The estimated signal to noise ratio is provided to comparator **320**. In comparator **320**, the estimated signal to noise ratio is compared to the threshold value (T). The power control command requesting that the transmitter either increase or decrease its transmission energy is determined in accordance with this comparison. The result of the comparison is provided to power control bit generator (PCB GEN) **322**. If the estimated signal to noise energy exceeds the threshold (T), then power control bit generator **322** provides a message requesting that the remote station reduce its transmission energy. Conversely, if the estimated signal to noise energy is less than the threshold (T), then power control bit generator **322** provides a message requesting that the remote station increase its transmission energy. One skilled in the art will understand that the present invention although described in terms of reverse link power control can be extended to forward link power control.

The power control command from power control bit generator **322** is provided to multiplexer **324**. In the exemplary embodiment, the power control commands are time multiplexed with the pilot signal and traffic data as described in the aforementioned copending U.S. Application Serial No. 08/963,386. One skilled in the art will appreciate that although illustrated in a system in which the power control commands are time multiplexed into the transmitted frames of data, the present invention is equally applicable to communication systems in which the power control bits are punctured into the transmitted signals such as in the cdma2000 or WCDMA proposed systems.

The multiplexed frames of data is modulated by modulator **326**. In the exemplary embodiment, the modulation is a spread spectrum communication signal. The modulated symbols are then provided to transmitter (TMTR) **328**. Transmitter **328** up converts, amplifies and filters the signal for transmission.

Turning now to FIG. 4, an expanded functional block diagram of metric calculators **302** is shown. As previously described, receiver (RCVR) **300** downconverts the received reverse link RF signals to a baseband frequency, producing I and Q baseband signals. In the exemplary embodiment, the received signal is complex PN spread using an in-phase PN_I sequence and a quadrature phase PN_Q sequence by methods that are well known in the art and are described in detail in the aforementioned U.S. Patent Application Serial No. 08/886,604. Despreaders **510** and **512** respectively despread the I and Q signals using the PN_I sequence. Similarly, despreaders **514** and **516** respectively despread the Q and I signals using the PN_Q sequence. The outputs of despreaders **510** and **512** are combined in combiner **518**. The output of

despreader **516** is subtracted from the output of despreader **512** in combiner **520**.

The respective outputs of combiners **518** and **520** are summed over one Walsh symbol by accumulators **530** and **532**. The outputs of accumulators **530** and **532** are provided to delay elements **531** and **533**, respectively. Delay elements **531** and **533** are provided in order to equalize the additional delay that the filtered pilot signal experiences as a result of the filtering operating performed by pilot filters **534** and **536**. The respective outputs of combiners **518** and **520** are also summed over one Walsh symbol by accumulators **526** and **528**. The respective outputs of accumulators **526** and **528** are then applied to pilot filters **534** and **536**. Pilot filters **534** and **536** generate an estimation of the channel conditions by determining the estimated gain and phase of the pilot signal data. The output of pilot filter **534** is then multiplied by the output of delay element **531** in multiplier **538**. Similarly, the output of pilot filter **536** is multiplied by the output of delay element **533** in multiplier **542**. The output of multiplier **542** is then summed with the output of multiplier **538** in combiner **546** to produce the demodulated pilot symbols.

In addition, the output of pilot filters **534** and **536** are provided to decimator **552**. In the exemplary embodiment, pilot filters **534** and **536** are moving average filters that average the amplitudes of the received pilot symbols over a slot duration. Decimator **552** samples the outputs of pilot filters **534** and **536** at slot boundaries to provide the average symbols amplitudes for each slot in the frame.

The average symbol amplitudes averaged over each slot in the frame are provided to energy calculator (I^2+Q^2) **554**. Energy calculator **554** sums the squares the amplitudes of the samples from pilot filters **534** and **536** and provides the resultant energy values to accumulator (ACC) 559. Accumulator 559 accumulates the energy of the slot over a frame duration and outputs the accumulated frame energy to set point calculator **316**. In addition, the average slot energy values from energy calculator **554** are provided to low pass filter (LPF) **556**. In the exemplary embodiment, low pass filter **556** computes the average pilot symbol energy over multiple slots and provides this value to comparator **558**. Comparator **558** compares the average pilot symbol energy to a threshold value and based on this comparison determines whether the finger is in lock. Comparator **558** outputs the result of the comparison to finger combiner **310**. It will be understood by one skilled in the art that there are

many variations on the method presented herein for determining whether a finger is in lock and that the method present is for illustrative purposes.

FIG. 5 provides an exemplary illustration of normalized signal variance calculator 315. The pilot symbol energies from accumulator 559 of each of pilot energy calculators 306 are summed in finger combiner 310 and provided to low pass filter (LPF) 560 and squaring element 562.

$\overline{p}(n)$

In the exemplary embodiment, low pass filter 560 is an single pole IIR averaging filter that computes the average symbol energy, $\overline{p}(n)$, of the combined pilot symbol energy over multiple frame duration. In the exemplary embodiment, the average symbol energy is computed in accordance with equation (2) above. The average symbol energy $\overline{p}(n)$ is provided to squaring element 561, which computes the square of the average symbol energy, $\overline{p(n)}^2$, and provides the value to a first input of summer 565.

Squaring element 562 squares the amplitudes of the combined symbol energies and provides the squared amplitude values to low pass filter (LPF) 563. Low pass filter 563 is an single pole IIR filter that computes the average of the squared energy values over the frame's duration, $\overline{p(n)^2}$. The output from low pass filter 563 is provided to a second summing input of summer 565. Summer 565 computes the sum of the square of the average symbol energy, $\overline{p(n)}^2$ and the average of the squared symbol energies, $\overline{p(n)^2}$ and provides that sum to the numerator input of divider 566. Low pass filter 562 also provides the average of the squared energies to the denominator input of diving element 566. Dividing element 566 divides the sum from summer 565 by the average of the squared energies from low pass filter 562. The result of the division is provided to square root element 567 which calculates the square root of the division performed by dividing element 566. In the exemplary embodiment, the square root operation is performed by means of a table look up. It will be understood by one skilled in the art that other methods of determining the square root value are known and can be applied to the present invention without departing from the application's scope.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is

to be accorded the widest scope consistent with the principles and novel features disclosed herein.

I CLAIM:

CLAIMS

1. In a first communication device in which at least two channels are transmitted and in which a first channel is transmitted during a larger percentage of the duration of a communication service than the remaining channels, an apparatus in a second communication device for determining the power control set point at a receiver of said at least two channels, comprising:

means for demodulating said first channel of a received signal;

means for demodulating said remaining channels of said received signal; and

means for determining said power control set point in accordance with said demodulated first channel.

2. The apparatus of Claim 1 wherein said first channel is a pilot channel.

3. The apparatus of Claim 2 wherein said remaining channels comprise a packet data transmission channel.

4. The apparatus of Claim 1 wherein said first communication device is a remote station and wherein said second communication device is a base station.

5. The apparatus of Claim 1 wherein said means for determining said power control set point, comprises:

means for calculating a pilot bit error rate; and

means for calculating said power control set point in accordance with said pilot bit error rate.

6. The apparatus of Claim 5 wherein said means for calculating said pilot bit error rate, comprises:

pilot bit demodulator for demodulating received pilot symbols; and

comparison means for comparing said demodulated pilot symbols to a predetermined pilot symbol sequence.

7. The apparatus of Claim 6 wherein said means for calculating said pilot bit error rate, further comprises:

means for determining at least one channel characteristic; and

wherein said means for calculating said power control set point calculates said power control set point in accordance with said pilot bit error rate and said at least one channel characteristic.

8. The apparatus of Claim 7 wherein said at least one channel characteristic comprises the relative velocity between said first communication device and said second communication device.

9. The apparatus of Claim 6 wherein said pilot bit demodulator means, comprises:

channel estimation means for generating a channel estimate in accordance with said received pilot symbols; and

dot product circuit for computing the dot product between channel estimate and said received pilot symbols.

10. The apparatus of Claim 6 wherein said channel estimation means comprises:

Walsh summing means for accumulating a predetermined number of pilot symbols; and

pilot filter means for low pass filtering said accumulated pilot symbols.

11. The apparatus of Claim 6 wherein said pilot bit demodulator means, comprises:

complex PN demodulator for demodulating said received signal in accordance with a complex PN despreading format;

pilot despreading means for despreading said complex PN demodulated signal;

channel estimation means for despreading said complex PN demodulated signal and for filtering said despread signal; and

dot product means for computing the dot product of said despread signal and said channel estimate to provide said demodulated pilot symbols.

12. The apparatus of Claim 6 wherein said pilot bit demodulator means, comprises:

plurality of pilot demodulators wherein each of said plurality of pilot demodulators demodulates a corresponding finger of a diversity receiver to provide pilot symbol energies; and

combiner means for receiving said pilot symbol energies and for combining said pilot symbol energies.

13. The apparatus of Claim 5 wherein said means for determining said power control set point, further comprises:

means for determining said pilot variance; and

wherein said means for calculating said power control set point performs said calculation in accordance with said pilot variance.

14. The apparatus of Claim 13 wherein said means for determining said pilot variance comprises:

pilot symbol energy calculator means for computing energies of said demodulated pilot symbols; and

variance calculator for calculating the variance of said energies of said demodulated pilot symbols.

15. The apparatus of Claim 13 wherein said means for determining said pilot variance comprises:

plurality pilot symbol energy calculator means wherein each of said pilot symbol energy calculator means is for computing energies of said demodulated pilot symbols of a corresponding finger of a diversity receiver;

combiner means for combining said energies of said pilot symbols; and

variance calculator means for calculating the variance of said combined energies of said demodulated pilot symbols.

16. The apparatus of Claim 14 wherein said variance calculator means comprises:

first filter means for receiving said demodulated pilot symbol energies and for filtering said pilot symbol energies;

first squaring means for receiving said filtered demodulated pilot symbol energy and squaring said filtered demodulated pilot symbol energy to provide an average squared pilot symbol energy;

second squaring means for receiving said demodulated pilot symbol energies and squaring said pilot symbol energies;

second filtering means for receiving said squared demodulated pilot symbols to provide a squared average pilot symbol energy;

summing means for receiving said average squared pilot symbol energy and said squared average pilot symbol energy and for summing said average squared pilot symbol energy and said squared average pilot symbol energy; and

divider means for receiving said sum of said average squared pilot symbol energy and said squared average pilot symbol energy and for receiving said average squared pilot symbol energy and for dividing said sum of said average squared pilot symbol energy and said squared average pilot symbol energy by said average squared pilot symbol energy.

17. The apparatus of Claim 13 wherein said means for calculating said means for calculating said power control set point calculates said set point in accordance with a linear combination of said pilot variance and said pilot symbol error rate.

18. The apparatus of Claim 13 wherein said means for determining said power control set point further comprises:

means for computing an average number of fingers in lock; and

wherein said means for calculating said power control set point performs said calculation in accordance with said average number of fingers in lock.

19. In a first communication device in which at least two channels are transmitted and in which a first channel is transmitted during a larger percentage of the duration of a communication service than the remaining channels, a method for determining the power control set point at a receiver of said at least two channels, comprising the steps of:

demodulating said first channel of a received signal;

demodulating said remaining channels of said received signal; and

determining said power control set point in accordance with said demodulated first channel.

20. The method of Claim 19 wherein said first channel is a pilot channel.

21. The method of Claim 20 wherein said remaining channels comprise a packet data transmission channel.

22. The method of Claim 20 wherein said first communication device is a remote station and wherein said second communication device is a base station.

23. The method of Claim 19 wherein said step of determining said power control set point, comprises the steps of:

calculating a pilot bit error rate; and

calculating said power control set point in accordance with said pilot bit error rate.

24. The method of Claim 23 wherein said means for calculating said pilot bit error rate, comprises the steps of:

demodulating received pilot symbols; and

comparing said demodulated pilot symbols to a predetermined pilot symbol sequence.

25. The method of Claim 24 wherein said means for calculating said pilot bit error rate, further comprises:

determining at least one channel characteristic; and

wherein said step of calculating said power control set point calculates said power control set point in accordance with said pilot bit error rate and said at least one channel characteristic.

26. The method of Claim 25 wherein said at least one channel characteristic comprises the relative velocity between said first communication device and said second communication device.

27 The method of Claim 24 wherein said step of demodulating said pilot symbols, comprises the steps of:

generating a channel estimate in accordance with said received pilot symbols; and

computing the dot product between channel estimate and said received pilot symbols.

28. The method of Claim 24 wherein said step of generating a channel estimate comprises the steps of:

accumulating a predetermined number of pilot symbols; and

low pass filtering said accumulated pilot symbols.

29. The method of Claim 24 wherein said step of demodulating pilot symbols, comprises the steps of:

demodulating said received signal in accordance with a complex PN despreading format;

despreading said complex PN demodulated signal;

despreading said complex PN demodulated signal and for filtering said despread signal; and

computing the dot product of said despread signal and said channel estimate to provide said demodulated pilot symbols.

30. The method of Claim 24 wherein said step of demodulating said pilot symbols, comprises the steps of:

demodulating a plurality of pilot signals wherein each of said plurality of pilot signals corresponds to a finger of a diversity receiver; and

combining said pilot symbol energies generated from said step of demodulating.

31. The method of Claim 23 wherein said step of determining said power control set point, further comprises:

determining said pilot variance; and

wherein said step of calculating said power control set point performs said calculation in accordance with said pilot variance.

32. The method of Claim 31 wherein said step of determining said pilot variance comprises the steps of:

computing energies of said demodulated pilot symbols; and

calculating the variance of said energies of said demodulated pilot symbols.

33. The method of Claim 31 wherein said step of determining said pilot variance comprises:

computing a plurality pilot symbol energies wherein each of said pilot symbol energies corresponds to a finger of a diversity receiver;

combining said energies of said pilot symbols; and

calculating the variance of said combined energies of said demodulated pilot symbols.

34. The method of Claim 32 wherein said step of calculating the variance comprises the steps of:

filtering said pilot symbol energies;

squaring said filtered demodulated pilot symbol energy to provide an average squared pilot symbol energy;

squaring said pilot symbol energies;

filtering said squared demodulated pilot symbols to provide a squared average pilot symbol energy;

summing said average squared pilot symbol energy and said squared average pilot symbol energy; and

dividing said sum of said average squared pilot symbol energy and said squared average pilot symbol energy by said average squared pilot symbol energy.

35. The method of Claim 31 wherein said step of calculating said power control set point calculates said set point in accordance with a linear combination of said pilot variance and said pilot symbol error rate.

36. The method of Claim 31 wherein said step of determining said power control set point further comprises the steps of:

computing an average number of fingers in lock; and

wherein said step of calculating said power control set point performs said calculation in accordance with said average number of fingers in lock.

PRIOR ART

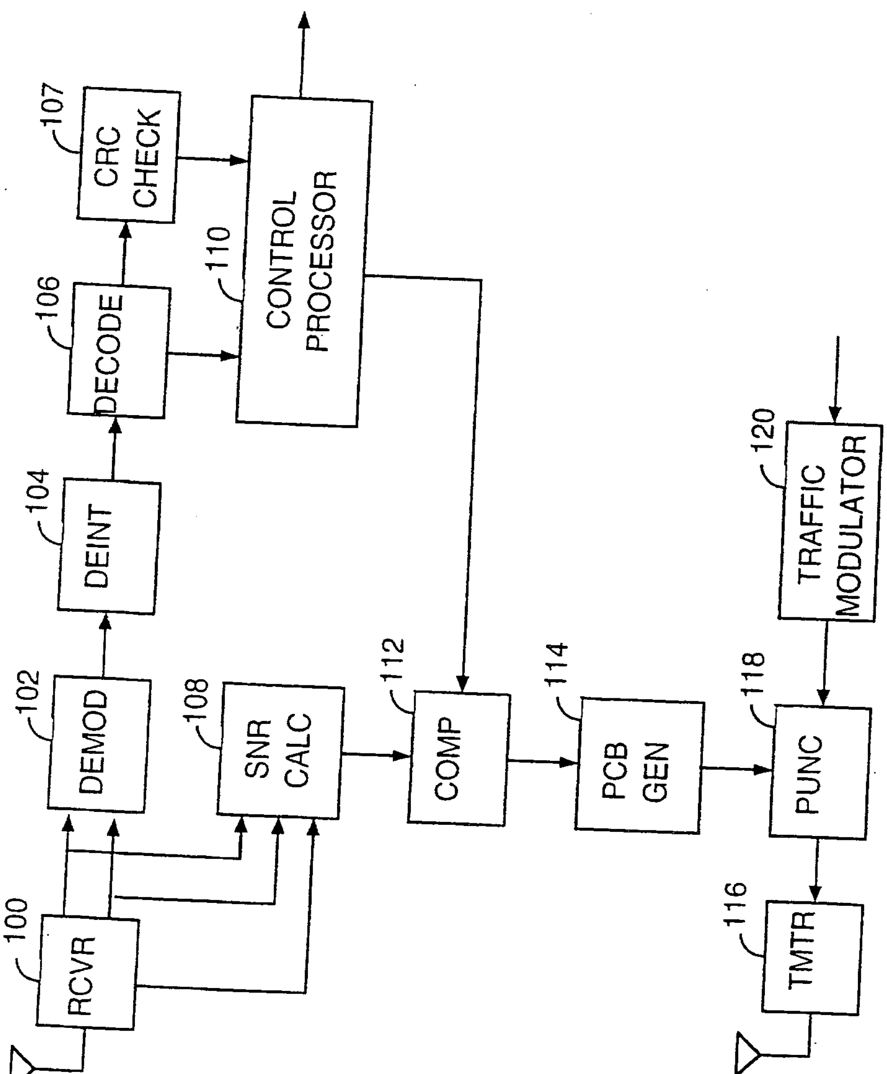


FIG. 1

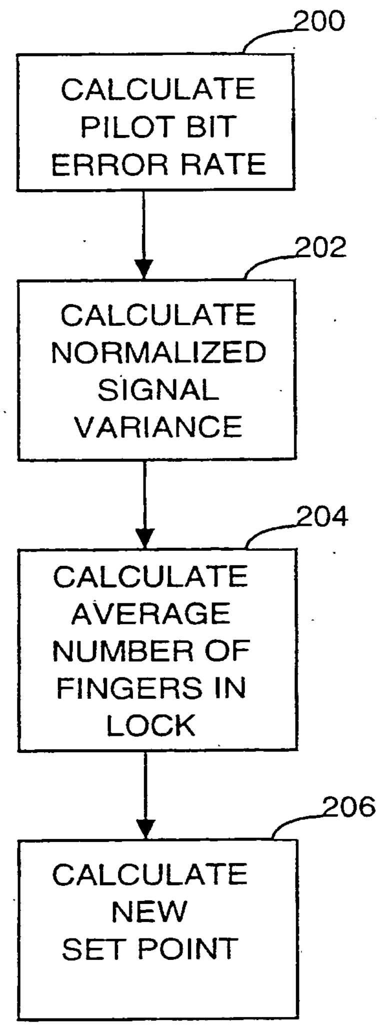
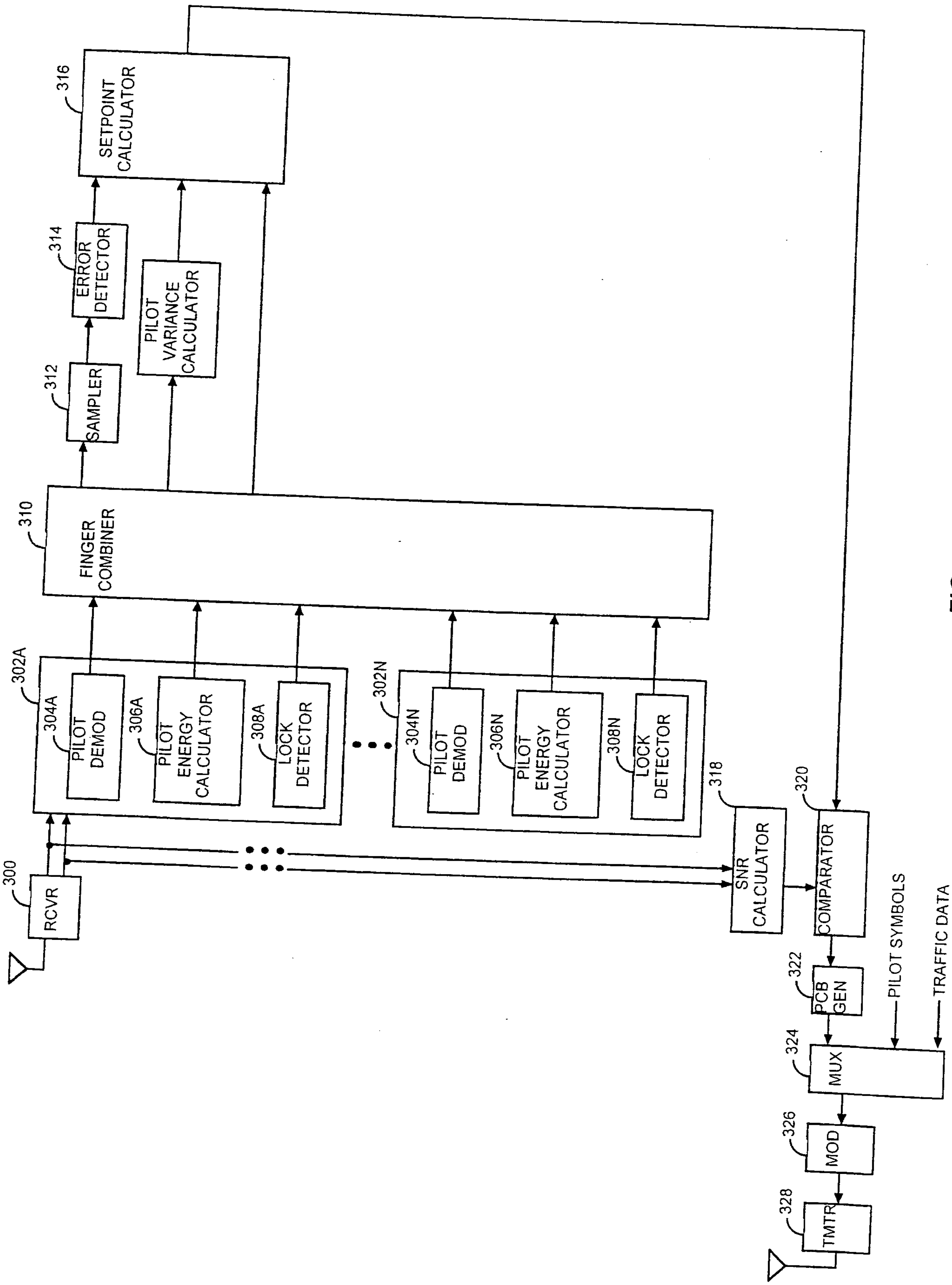

200
CALCULATE PILOT BIT ERROR RATE
202
CALCULATE NORMALIZED SIGNAL VARIANCE
204
CALCULATE AVERAGE NUMBER OF FINGERS IN LOCK
206
CALCULATE NEW SET POINT

FIG. 2


316
SETPOINT CALCULATOR
314
ERROR DETECTOR
312
SAMPLER
PILOT VARIANCE CALCULATOR
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FINGER COMBINER
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306A
PILOT ENERGY CALCULATOR
308A
LOCK DETECTOR
302N
304N
PILOT DEMOD
306N
PILOT ENERGY CALCULATOR
308N
LOCK DETECTOR
300
RCVR
318
SNR CALCULATOR
320
COMPARATOR
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PCB GEN
PILOT SYMBOLS
TRAFFIC DATA
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MUX
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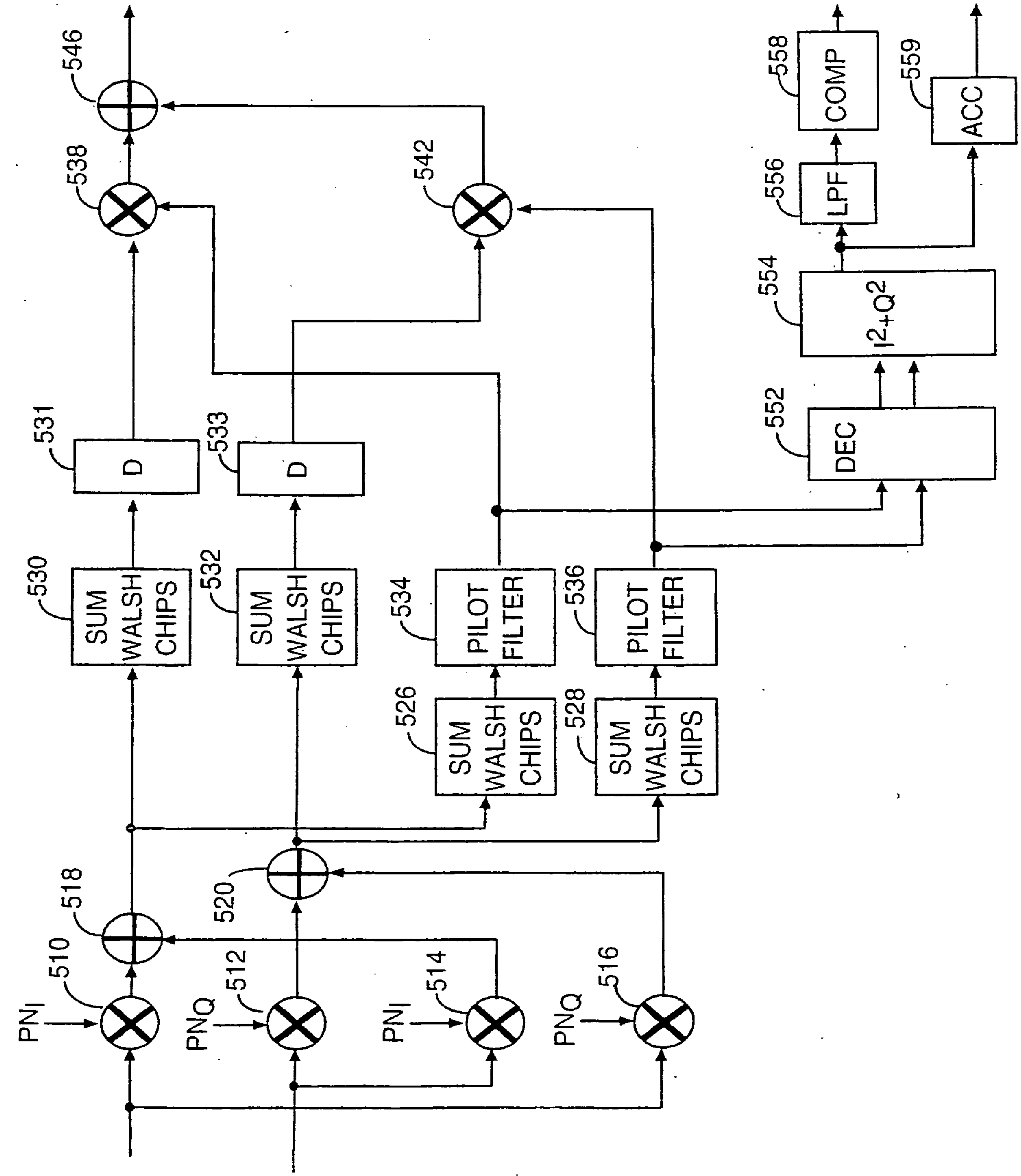
MOD
328
TMTR

FIG. 3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536
PILOT FILTER
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LPF
558
COMP
559
ACC

FIG. 4

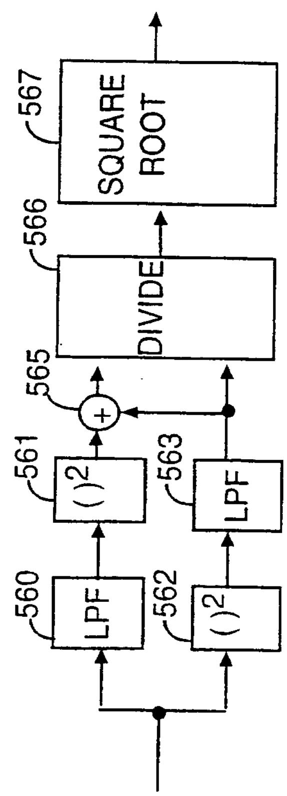

FIG. 5

INTERNATIONAL SEARCH REPORT

Internati Application No
PCT/US 00/21442

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

INSPEC, WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 933 781 A (ODENWALDER JOSEPH P ET AL) 3 August 1999 (1999-08-03) column 3, line 1 - line 14 column 3, line 32 -column 6, line 31	1-4, 19-22 5-8,13, 23-26,31
X A	WO 99 18702 A (MOTOROLA INC) 15 April 1999 (1999-04-15) page 1, line 21 - line 27 page 8, line 25 -page 10, line 14 page 11, line 10 - line 31 page 15, line 9 - line 21 page 18, line 26 -page 20, line 17	1-4, 19-22 5-17, 23-35

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 November 2000	15/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gerling, J.C.J.

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INTERNATIONAL SEARCH REPORT

Internati Application No
PCT/US 00/21442

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 853 393 A (NIPPON TELEGRAPH & TELEPHONE) 15 July 1998 (1998-07-15) column 2, line 32 - line 44 column 3, line 8 - line 32 column 4, line 10 - line 42 column 8, line 4 - line 55 ---	5-8,13, 23-26,31
A	WO 99 10985 A (QUALCOMM INC) 4 March 1999 (1999-03-04) -----	

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

In. . .mation on patent family members

Internatl Application No
PCT/US 00/21442

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5933781	A	03-08-1999	AU	6032498 A	25-08-1998
			BR	9807533 A	14-03-2000
			CN	1256030 T	07-06-2000
			EP	0956661 A	17-11-1999
			WO	9834356 A	06-08-1998
WO 9918702	A	15-04-1999	US	5946346 A	31-08-1999
			EP	1021899 A	26-07-2000
EP 0853393	A	15-07-1998	CA	2230778 A	31-12-1997
			CN	1198274 A	04-11-1998
			WO	9750197 A	31-12-1997
WO 9910985	A	04-03-1999	US	6097972 A	01-08-2000
			AU	9118098 A	16-03-1999
			EP	1010258 A	21-06-2000